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COMPLETE SPECIFICATION

Improvements in Electric Lighting Control Systems

I, ROLLO GILLESPIE WILLIAMS, of 20, Clent Road, Great Neck, Long Island, New York, United States of America, a British Subject, do hereby declare the invention for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electric lighting control systems and particularly to a novel method and means for controlling the selection of hues of colours in a colour lighting system and also the light values of the selected hues and combining the hues thus selected whereby illuminations having a wide range of resultant hues of colour will be produced.

In the systems of colour lighting using a plurality of sources of colour, such as those systems largely employed heretofore in theatres, motion-picture houses, shop windows, ball-rooms, and other places where colour lighting is desired either for dramatic effect or for decorative or display purposes, it has been found necessary to employ in the control apparatus more than one brightness control for the plurality of sources of colour. This requirement obviously not only greatly increases the cost of the control apparatus but also necessitates greater space for containing it. One of the objects of the present invention is to minimize the cost and the space requirements of a colour lighting system employing a plurality of sources of colour, that effect being attained by means in which the voltage regulation of a plurality of sources of colour is effected by means of a single brightness control.

In the production of pastel hues of colour in a colour lighting system by combining white light with coloured light, it is of course necessary to maintain the intensity of the white illumination at a low value with respect to the light values of the coloured illumination in order to prevent the overpowering of the coloured light by white light which would result in the production of off-white illumination instead of pastel hues. In the present invention, when electrical sources of white light and coloured light are employed, the control of the intensity of the white light is effected by an unusual arrangement of the control circuit by which one of the sources of coloured light is connected in series with the source of white light so as to reduce the voltage applied to the source of white light, the source of coloured light thus connected in series with the white light being one which during the period of activation of the other sources of light would otherwise remain inactivated. In a lighting system employing red, green, blue, and white, in which one of the sources of colour is connected in series with the source of white to reduce its intensity, as mentioned above, the pastelling effect produced by white light of reduced intensity is enhanced by the light produced by the colour source that is in series with the white source, since the hue of that colour source is always the complementary hue of that produced by the other two colours and therefore contributes to the pastelling of the resulting hue of said other two colours. On some occasions an essentially white light is required which can be modified to appear "warm," i.e., blended with red light source or "cold," i.e., blended with a blue light source. Additionally the present invention provides for the production of off-white colours of an infinite variety of hues. For this purpose the intensity of the electrical source of white light is controlled solely by the dimmer, there being provided switching means for connecting the electrical sources of coloured light to the electrical supply some directly and some through the dimmer so as to obtain different blends of varying colour intensities with white light.

In some lighting control systems heretofore employed, which required the use of variable auto-transformers, it was necessary

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to provide a transformer in which some of the turns of the winding at the high-voltage end thereof were replaced by a conductive plate on to which the movable contact member of the transformer would ride when it reached that end of the coil, such arrangement being essential to avoid the burning out of the transformer by the short-circuiting of one or a few turns of the winding at the high-voltage end during the switching operations of the control circuit. One of the advantages of the present invention, which will be fully described hereinafter, resides in the fact that the switching means employed entirely removes the possibility of short-circuiting any of the turns of the winding of the transformer during the operation of the control apparatus and therefore permits the employment of standard types of auto-transformers.

In its basic form, therefore, the invention provides control apparatus for colour lighting comprising a plurality of electrical sources of coloured light and an electrical source of light of paler colour than those of the other sources, a single variable dimmer, switching means for the coloured light sources which enables one coloured light source to be connected to an electrical supply at full voltage and another coloured light source to be connected to the supply through the dimmer, operating means for the switching means and the dimmer, and further switching means to enable the paler source of light to be connected to the supply either directly through the dimmer or through the dimmer and a source of coloured light not in any other way connected to the supply. Conveniently, the improved apparatus comprises, in combination, three electrical sources of coloured light, each of the colours of which is approximately the complementary colour of a hue resulting from the combination of coloured light of the other two sources, an electrical source of light of paler colour than those of said other sources, a single variable dimmer, switching means to select a source of coloured light and to apply the dimmer voltage thereto, a single operating member for the dimmer and the switching means, said switching means being arranged simultaneously to maintain the application of a constant voltage to another of the said sources of coloured light and to connect the third source of coloured light in series with the light source of paler colour and said dimmer.

The control element may be adapted to operate the switching means and dimmer progressively through a complete cycle of colour change whereby each light source in turn is brought from minimum to maximum intensity gradually, is maintained at maximum intensity for a period and then returned to minimum intensity gradually, and wherein each terminates its said period of maximum intensity as or approximately as the next in turn begins its same period.

In representative embodiments of the invention, one of which is more fully described below, the apparatus comprises three electrical sources of coloured light each of the colours of which is approximately the complementary colour of a hue resulting from the combination of coloured light of the other two sources, a pair of switches associated with each such light source and a plurality of rotating cams for operating the respective switches, a rotary dimmer and means for rotating the cams and dimmer simultaneously so that each light source in turn is brought gradually from minimum to maximum voltage, is maintained at maximum voltage and is then brought gradually back to minimum voltage, and so that each source begins to decline in voltage as or approximately as the next in turn reaches the maximum, with separately-operated switch means for connecting the other source, or a white light source, or both, to the supply in series with the dimmer.

The invention is further characterised by the inclusion of a chromatic scale showing the hues of colour that are attainable by this invention, the scale having associated with it a pointer the movements of which result from those of a control knob whereby the apparatus may be set to produce illumination of any desired colour.

Furthermore, each control unit is arranged not only for the manual adjustment of the apparatus contained in said unit whereby any hue of colour upon the associated chromatic scale may be produced at will by the group of lamps controlled by said apparatus, but the unit is also designed to be motor-operated whereby the entire range of hues of colours of said scale may be repetitively produced. Furthermore, said apparatus is arranged to be locked in either the manually-operated position or the motor-operated position, as desired. Obviously, a plurality of such units may be grouped in a suitable framework so that all may be operated by the same driving means. Furthermore, since the control units may be readily changed from the manually-operated position to the motor-operated position, and vice versa, and locked in either of said positions, certain units in such a group of units may be set for motor-operation and others set for manual-operation, thereby producing an illumination effect in which the colours repetitively produced by the light sources controlled by the motor-operated units will be contrasted with the hues of colour of the light sources controlled by the manually-operated units, and indicated by the particular setting thereof. For example, one of the units in a group may control one set of

side lights in a window lighting system, a second unit may control another set of side lights, and a third unit may control the set of lights at the top of the window, and the units of the group may be adjusted so that the illumination from the side lights will continuously vary while that from the top lights will remain fixed thereby producing the desired colour effect. When all units are connected so as to be operated continuously, they may be set to begin the production of colour at different points upon a chromatic scale, such as that described hereinafter, and after being thus set, the switching mechanism of the several units will maintain throughout the entire sequence of hues of colour the same relationship between the hues produced by the several units that existed at the initial setting of the units, thereby producing unusual and striking colour effects.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawings, in which:—

Fig. 1 is a circuit diagram representing one form of the invention;

Fig. 2 is a chart showing the time of operation of the cams shown in Fig. 1 throughout the one complete colour cycle of 360°;

Fig. 3 shows the voltage curve of the single dimmer employed in this invention throughout a complete colour cycle, and also shows the curve of intensity of white light (when used) in lumens corresponding to the voltage variation;

Fig. 4 is a perspective view of one form of the driving and timing apparatus employed in the circuit shown in Fig. 1; and Fig. 4A is a detail of the apparatus shown on Fig. 4;

Fig. 5 is a circuit diagram of a modification of the circuit in which the present invention is employed;

Figs. 6, 6A, and 6B show an arrangement for coupling together a plurality of control units and operating them from the driving means connected to one of said units;

Figs. 7 and 7A are modifications of a portion of the circuit of Fig. 1, Fig. 7 showing means by which the normally inactive source of colour in a three colour lighting system may be beneficially employed by connecting said source to the dimmer in series with a resistance to control the intensity of light of said source; and Fig. 7A shows means by which the normally inactive source of colour in a four colour lighting system may be employed either in combination with two of said colours as in Fig. 7 or with three of said colours in the manner shown in Fig. 1;

Figs. 8 and 8A are modifications of a portion of the circuit in Fig. 5 showing two other ways in which the intensity of the white light in said circuit may be controlled; and

Fig. 9 is a colour chart for use in a lighting system employing white, red, green, and blue sources of light showing the range of hues of colour resulting from the sequence of adjustments of the apparatus in which the present invention is embodied.

Throughout the following description of this invention, it has been assumed, for the purpose of illustration, that each source of white light is an incandescent lamp and that coloured light is obtained by passing white light through colour filters in the manner described in my book entitled "The Technique of Stage Lighting" published in 1947 by Sir Isaac Pitman & Sons, London. At the outset, in order to avoid misunderstanding, it is essential to point out that the lumen values represented by the "Lumens" curve shown in Fig. 3 are solely those of the source of white light; they do not indicate the light value of coloured light that may be produced by passing white light through a colour filter.

In Fig. 1, which shows a preferred form of the invention, 100 and 101 represent the conductors of a supply circuit for the operation of a four-colour lighting system employing a source of white light and sources of red, green, and blue light, with which the present control apparatus is associated. Across this supply circuit is connected the winding of an auto-transformer 1, the movable contact member 2 of which is connected to the lamps of the lighting system, the mode of connection of which will presently be fully described. For convenience, the conductor 100 is referred to hereinafter as the live side of the supply circuit, and conductor 101 as the neutral or grounded side thereof, but it is to be understood that the control system will work equally well if those conditions in the circuit are reversed.

The control apparatus employs a plurality of low pressure, small displacement switches, as, for example, "Micro-switches," which are designated A to F, inclusive, in the figure. The upper contact points 3 of switches A, C, and E, are connected to conductor 100 of the lighting circuit. The lower contact points 4 of the switches A, C, and E, are connected to the conductor 53 which, in turn, is connected to the contact member 2 of the auto-transformer; and the movable contact members 5 of each of the switches, A, C, and E, are connected to the upper contact members 6 of each of the switches B, D, and F, respectively. The lower contact points 7 of each of the latter switches are connected to conductor 45 which, in turn, is connected to contact point 8 of a manually-operated switch 9 which is associated with the white lighting circuit. The movable contact members 10 of each of the switches

B, D, and F, are connected to the red, green, and blue lamps, respectively. Associated with the movable contact members 5 of switches A, C, and E, are cams, as 11, 12, and 13, respectively, and similarly associated with the movable contact members 10 of switches B, D, and F, are cams, as 14, 15, and 16, respectively, said cams serving as controlling means for the switches. While the two groups of cams are shown mounted upon separate rotatable shafts in Fig. 1 (indicated by the dot-and-dash lines), such showing is merely for the sake of clarity since it is preferable to mount all cams upon the same shaft, such as 30 in Fig. 4. A colour chart, as 46, and an indicator, as 31, in Fig. 4, will show the hues of colour throughout the range of colours produced by the colour lighting system during the rotation of the shaft 30 through the angular distance of 360°. Each of the cams, 11, 12, and 13, has two operating surfaces, and each of the cams, 14, 15, and 16, has one operating surface, the length of the operating surfaces and their relative positions in a preferred embodiment of the invention being as shown diagrammatically in Fig. 2. The white lamp is connected to the movable contact member 17 of the switch 9, the lower contact point 18 of which is connected to conductor 101 representing the neutral or grounded side of the supply circuit. Each of the circuits may be protected by circuit breakers, such as 41, or by switch-fuses in accordance with conventional practices, if desired.

The manner in which the control circuit of Fig. 1 is operated to select sources of light and to regulate their intensity, will be described first as limited to the use of sources of coloured light solely, and thereafter a description will be given of the mode of operation of the circuit to effect the production of pastel hues and off-white colours.

Referring to the graph, Fig. 2, this shows by the darkened areas the time of operation and the duration of operation of each of the switches A to F, inclusive, by the cams 11 to 16, inclusive but it should be noted that this timing is not in step with the disposition of the switches A—F in Fig. 1, that figure showing all the cams in their neutral positions. It will be seen that at the beginning of the colour cycle of 360°, switches A, C, and F, are then in operation, having previously been operated by the cams 11, 12, and 16, respectively, associated therewith, switch B has just been released and the switch D will be operated immediately by the action of the cam 15. Accordingly, at that instant contacts 4 of switches A and C will be closed and likewise contacts 6 of switches D and F. Through contact 6 of switch F a circuit will be closed which will extend from the conductor 100 to conductor 101 of the supply circuit and will include contact 3 of switch E, contact 6 of switch F, and the blue lamp, which will produce blue light which will be of maximum intensity since the voltage applied thereto is the full line-voltage. Through the operation of switches C and D a circuit is established that extends from the movable contact member 2 of the auto-transformer to conductor 101 of the supply circuit and includes conductor 53, contacts 4 and 6 of switches C and D, respectively, and the green lamp, thereby applying the dimmer voltage to that lamp. The switch A remains operated through the angular distance of about 15° and then is released. This prolongation of the time of operation of switch A is to prevent the connection of the red lamp directly across the supply circuit 100—101, and the undesired production of a flash of red light of full value, which would be the result if the release of switch A occurred prior to the release of switch B.

Referring to Fig. 3, which is in step with the diagram in Fig. 2, it will be seen that at the beginning of the cycle the dimmer voltage is a minimum, viz., 20 volts, and in consequence thereof, there will be substantially no illumination produced by the green lamp. As the contact member 2 moves along the winding of the auto-transformer, the voltage increases as shown in Fig. 3 and reaches the full line-voltage viz. 120 volts, at 60° of the full colour cycle of 360° as represented by the colour chart shown in Fig. 9. It will be noted that throughout the period in which the intensity of green light has been gradually increasing the blue light has remained constant at maximum intensity. Accordingly, there will be a merging of those colours, the blue predominating during the early part of the period of time until the green light reaches its maximum at 60°, when green light and blue light will be at full intensity.

Referring again to Fig. 2, it will be seen that shortly before the 60° point is reached, the cam 12 releases switch C while switches D and F remain operated. Shortly after the release of switch C, switch E will be operated by cam 13. It is desirable to mention that each of the cams operating switches A, C, and E, is designed to release its controlled switch at 180°, 60° and 300°, upon the colour cycle, before the next switch of that group is operated, so as to insure that at those points on the colour cycle, which are points of maximum voltage, only one colour circuit is connected to the dimmer when its voltage is maximum. Upon the operation of switch E a circuit will be closed that will extend from the contact member 2 of the dimmer to conductor 101 and will include conductor 53, contacts 4 and 6 of switches E and F, respectively, and the blue lamp, thereby connecting that lamp to the dimmer circuit. Upon the release of switch C its

contact 3 is closed, and since contact 6 of switch D remains closed, the green lamp will be connected directly across the supply circuit. The net result is that both colours, viz., blue and green, are still present in the illumination at almost identically the same strength as before those changes occurred. If the switches are of snap action type, as, for example, "Micro-switches," the change in the connections cannot be discerned by the eye because the lamp circuit is broken during an extremely short period, approximately 1/200th of a second, and the lamp filament does not lose all its heat in that time. Referring again to Fig. 3, it will be seen that from 60° onward, green light is at full intensity whereas the intensity of blue is diminishing; accordingly, green will dominate throughout that range, producing shades of blue-green, and that condition will continue until the switch F releases at the 120° point in the colour cycle when blue vanishes.

Shortly before the 120° point in the colour cycle is reached, switch A will be operated, and at the 120° point switch B will be operated, thereby connecting the red lamp to the dimmer the connection being timed to occur at the point of minimum voltage. Switch D remains operated at 120°, which maintains the green light at maximum intensity. Switch F will be released at the 120° point, as mentioned before, and switch E will be released shortly thereafter, thereby disconnecting the blue lamp. Thereafter the dimmer voltage will rise and the intensity of red light will increase, reaching maximum light value at 180° of the colour cycle. Consequently, throughout the period from 120° to 180° the hues of colour will be a combination of green and red ranging through yellow-green to yellow.

Shortly before the 180° point is reached, switch A is released, and shortly beyond that point switch C is operated. At 180° switches B and D remain operated. The continuance in operation of switch B after release of switch A connects the red lamp across the supply circuit 100-101 which applies the full line-voltage to that lamp and thus maintains the intensity of red illumination at maximum light value throughout the range from 180° to 300°. The operation of switch C and the continuance in operation of switch D connects the green lamp to the dimmer, the voltage of which is, as shown in Fig. 3, gradually diminishing, reaching its minimum at 240° whereupon the green light vanishes. In the period between 180° and 240°, the illumination will be a combination of red and green light in which red will predominate, thereby producing hues of colour ranging from yellow through orange to red. At 240° switch D will be released and switch C shortly thereafter. Shortly before the 240° point, switch E will be operated, and at 240° switch F will be operated, and switch B remains operated. The operation of switches E and F connects the blue lamp to the dimmer and by the continuance of operation of switch B the red lamp remains connected across the supply circuit. Accordingly, from 240° to 300° red will be at maximum intensity and blue will rise to the maximum light value at 300°, thereby producing combinations of red and blue in which red will predominate. Switch E will be released shortly before the 300° point is reached, and switch A will be operated shortly thereafter, thus effecting the connection of the blue lamp across the supply circuit and the red lamp to the dimmer, the voltage of which is diminishing. Accordingly, in the last period of the colour cycle, there is a combination of red and blue, in which blue will predominate. It should be noted that at 60°, 180° and 300°, which are points of maximum dimmer voltage, the cams are designed to provide separation in point of time between the release of one of the switches of the group A, C and E, and the operation of another switch of that group, this separation, which may be of the order of 6° to 10°, being desirable because it ensures the disconnection of one lamp from the dimmer before the connection thereto of another lamp, thereby preventing the overloading of the dimmer.

During the course of operation of the control apparatus just described, only the deep colours, red, green and blue, have been employed in effecting the range of hues of illumination that is produced by the combination of those colours. In order to extend the range of hues of colour, as, for example, to produce pastel hues, it is necessary to combine some white light and/or light of the complementary colour with the deep colours previously mentioned, the intensity of the white light thus introduced being preferably about 10% of the lumen value of the white source at the full voltage normally applied thereto. The combining of white light with coloured light is effected, in the circuit of Fig. 1, by the closing of the contact between the movable member 17 of switch 9 and the contact point 8 thereof. That operation not only introduces white light into a combination of coloured light, but also automatically adjusts the intensity of the white light thus introduced, that adjustment in intensity of white light being effected by a reduction in the voltage applied to the white source in a novel manner which will now be described.

It will be noted that during the operation of the control circuit, as previously described, one or other of the coloured lamps is, at any instant, connected directly across the lighting circuit so that the full line-voltage will be applied thereto, another coloured

lamp is connected to the dimmer the voltage of which varies cyclically between a minimum and a maximum, and the third coloured lamp has no voltage applied to it, such being the condition of the red lamp during the period from 0° to 120°, the blue lamp during the period from 120° to 240°, and the green lamp during the period from 240° to 360° of the colour cycle. Since those idle lamps represent electrical resistance, use is made of them to reduce the voltage across the white lamp, the manner of doing which is as follows:—

When the movable member 17 of switch 9 is operated upwardly so as to close its contact 8, the white lamp will be connected through contact 8 and conductor 45 to contacts 7 of the switches B, D and F. Referring to Fig. 2 it will be seen that during the period from 0° to 120°, switches D and F are operated and in consequence their contacts 7 are open, but switch B is not operated during that period and consequently its contact 7 is closed. Accordingly, the red lamp will be connected in series with the white lamp W and the dimmer, and since both lamps have the same resistance value, the voltage applied to each of those lamps will be one-half of the dimmer voltage. In consequence the illumination given by the white lamp is markedly reduced, as shown by curve Y of Fig. 3, the maximum being about 10% of the full lumen output of the lamp at its normal voltage of 120 volts, which amount of white light has been found to be satisfactory for combining with colours to produce desired hues of pastel colours. It is of course obvious that in a circuit such as that shown in Fig. 1 in which a coloured lamp is connected in series with a white lamp to reduce the intensity of illumination of the white lamp, the coloured lamp will also be activated. In a four-colour system employing white, red, green and blue sources, the lamp that at a given time is connected in series with the white lamp, also has a pastelling effect, the reason for this being that the colour of the lamp in series with the white lamp is the complementary colour of the hue produced by the other two coloured lamps. For example, if red and green lamps are connected to the dimmer and to the line, respectively, the illumination of those colours will be equal in intensity when the dimmer voltage equals the line-voltage, and the resulting hue of that combination is yellow. That colour is the complementary colour of blue, which is the colour of the lamp then in series with the white lamp. Accordingly, the light from the blue lamp will contribute to the pastelling of the other of said colours. Upon referring to Fig. 3, it will be seen that during the middle of the period from 0° to 120° the control apparatus will effect the production of pastel hues by the introduction of a small amount of varying white light supplemented by the complementary effect of a small amount of varying red light in the manner above described; similarly, during the period between 120° and 240° the blue lamp will be connected in series with the white lamp and thus will contribute to the pastelling; and in the period from 240° to 360° the green lamp will be similarly connected and will function similarly to the red and blue colours. Hence, at the mid-point of each of those periods, that is to say, in the region in which the rate of change of the voltage curve is least, the illumination resulting from two selected deep colours (red and green in one instance, blue and red in the second, and green and blue in the third) will be modified not only by the addition of white of low intensity but also by the complementary colour of the hue resulting from the selected pair of colours so as to produce a range of pastel hues which theoretically are infinite in number.

From the foregoing description it will be apparent that by means of the novel control arrangement shown in Fig. 1, it is possible to control by an apparatus employing a single dimmer the intensity of light produced by four distinct sources simultaneously, at values of illumination that differ widely; for example, in the range between 45° to 50° of the colour cycle there would be present in the illumination produced by the colour lighting system, blue light of maximum intensity, green light approaching maximum intensity, white light approaching 10% of the lumen value of the white source at full normal voltage, and red light (the complementary colour of the resultant of green and blue) at a light value less than that of the white light.

When it is desired to produce a range of tinted whites, instead of pastel hues, it is necessary to control the colour lighting system so that white will predominate in the illumination, the deep colour being subordinate thereto. This illumination effect may be accomplished in the apparatus shown in Fig. 1 by operating the movable contact member 17 of switch 9 downwards so as to close its contact 18, and thereby connect the white lamp directly between the movable contact member 2 of the dimmer and the neutral or grounded side of the line 101. When the white lamp is thus connected the full voltage of the dimmer will be applied to that lamp and the intensity of white illumination in lumens will range from 0% to 100%. The effect to the eye when the white illumination exceeds say 25% of its full value, is that of white illumination tinted by whatever combination of deep colours may be selected by the operation of the switches shown in Fig. 1. The off-white hues resulting from the combining of intense white light with deep colours are designated in Fig. 9 in the seg-

ments within the inner circle of the chart as "Cold Whites," "Warm Whites" and "Flesh Whites," the Cold Whites being those in which the tinting is effected by the combination of blue and green light; the Warm Whites being those tinted by the combination of green and red; and the Flesh Whites being those tinted by red and blue in combination. The combinations of deep colours produce the hues that are indicated upon the outer circle of the chart and those hues give to the intense white the tints that are indicated upon the segments within the inner circle. It will, of course, be understood that in the production of off-white light the non-activated colour source, which in pastelling is connected in series with the white lamp, is entirely disconnected therefrom by the opening of contact 8 of switch 9 and therefore has no effect in the production of white light.

Fig. 4 shows one form of the apparatus for controlling the voltage and also the connections in the circuit hereinbefore described. The apparatus includes a driving shaft 20 to which is fixedly attached a pinion 21, a crank 22, and a knob 32, by which the shaft may be rotated manually. A crank-pin 23 is attached to the crank, the mode of attachment being such that the radial distance of the pin from the centre of rotation of the crank may be adjusted at will. An arm 24 which is movably connected to the crank-pin has at its outer end a rack 25 which meshes with a pinion 26 that is connected to a shaft 27, to which is fastened a contact member 28 which is in contact with the winding 59 of the stationary dimmer or other voltage-varying device 63. The contact member makes contact with the successive turns of the winding 59 when the shaft 27 is rotated in accordance with the forward and backward movements of the arm 24 and applies the dimmer voltage to the lamps shown in Fig. 1. The pinion 21 meshes with a gear 29 which is fixedly mounted upon the shaft 30 upon which is also mounted a plurality of cams 11 to 16, inclusive. The cams make contact respectively with the movable member 5 and 10 of the switches A to F, inclusive. The shaft 30 also carries a pointer 31, which, in the course of operation of the apparatus moves across a colour chart 46, shown in fragmentary form in Fig. 4 and fully in Fig. 9, which chart may be mounted within or upon the casing in which the apparatus is installed. The length of each of the two operating surfaces or projections upon each of the cams A, C, E, as shown in Fig. 2, may be of the order of 70° to 73°; and that of the projections upon cams B, D and F, may be 240° as shown in that figure. The cams are mounted upon the shaft 30 so that those surfaces or projections will come into play at the points upon the colour cycle indicated in Fig. 2 of the drawings.

The mode of operation of the control apparatus to produce a desired hue of colour by the lamps controlled thereby is as follows: The knob 32 is turned until the pointer 31, associated with the colour chart 46, is adjusted to indicate the desired colour. The turning of the knob 32 simultaneously effects the rotation of the gear 29 and the movement of the arm 24. The rotation of gear 29 causes the cams 11 to 16, inclusive, to rotate, and their movement effects the operation of the switches A to F, inclusive, in predetermined order as shown in Fig. 2. The movement of the arm 24 adjusts the position of the contact member 28 upon the winding 59 of the dimmer. Since the arm 24, the pinion 21, and the gear 29, move simultaneously, there is obviously a definite relationship between the instantaneous values of the dimmer voltage and the electrical connections of the lamp circuit which are controlled by the cams upon the shaft 30 to which the gear 29 is attached. That relationship is important because it is by virtue of it that the same wide range of colours shown on the chart of Fig. 9 may be reproduced again and again by the lighting control system in which this invention is embodied. When the shaft 20 makes one revolution, the contactor 28 of the dimmer will be moved from one terminal of the dimmer winding to the other terminal thereof and back again to the first terminal, thereby causing the voltage applied to a given lamp to vary through a complete cycle of voltage as shown in Fig. 3. During that time the gear 29 will be moved by the pinion 21 through one-third of a complete revolution since the ratio of the gear to pinion, in the case assumed for illustrating the invention, is three to one. Acordingly, the pointer 31 which is fastened to the shaft 30 will move through 120° of the full colour cycle of the chart 46, and thereafter will move through the same angular distance for each complete revolution of the pinion 21, and for the full 360° of the colour cycle there will be three cycles of dimmer voltage as shown by Figs. 2 and 3. When the cams are correctly proportioned and proerly positioned upon the shaft 30, they will operate and release the switches A to F at the times indicated in Fig. 2 and will maintain them operated during the periods indicated. Since the cams and the dimmer are controlled by the same controlling means, viz., the knob 32 and the shaft 20, and since the ratio of the pinion to the gear 29 is fixed, the relationship between the dimmer voltage and the action of the cams is likewise fixed so that the same desired hue of colour may be obtained, over and over, by merely setting the pointer 31 at the point upon the chart 46 that shows the desired hue. When the pointer is thus set, the proper switches will have been operated to connect one of the coloured lamps to the

dimmer, another coloured lamp across the supply circuit, and in the case of pastel shades, the third coloured light in series with the white lamp and the dimmer; and the voltage of the dimmer is automatically adjusted to produce light of the proper intensity or light value that when combined with light from the source connected across the supply circuit will create the desired hue of colour. For the sake of clarity, the electrical connections have been omitted from Fig. 4, but it is to be understood that the apparatus shown in the latter figure may be connected either in the manner shown in Fig. 1 or Fig. 5, the latter of which will presently be described.

Fig. 4A shows a modification of the arrangement of the cams for the control of the "Micro-switches" by which six switches may be operated by two cams instead of six cams as in the arrangement of Fig. 4. The cam 64 has thereon two raised surfaces which coast with the movable members of switches A, C and E, to effect their operation, the length of these surfaces and the spacing being that indicated in Fig. 2. The cam 65 has thereon a single raised surface 240° in length as shown in that figure which controls the operation of switches B, D and F. When those cams are correctly positioned upon the shaft 30, the operation of the switches and the circuits controlled thereby will be similar to that shown in Fig. 4 and described hereinbefore.

The arrangement shown in Fig. 5 is a modification of that shown in Fig. 1, the modification consisting in the use of two white lamps which may be connected in parallel, when greater intensity of white light is desired, or in series with each other to cut down the voltage supplied to each lamp when it is desired to reduce the intensity of white light. In the circuit shown in Fig. 5, the switches A, C and E are double-throw, double - pole switches, preferably of the "Micro-switch" type similar to those shown in Fig. 1; the switches B, D and F are single-pole, single-throw switches, preferably of the same type as the switches A, C and E, all said switches are mounted preferably upon the same shaft, as shown in Fig. 4, but they may be mounted upon separate shafts as mentioned hereinbefore. The switches A to F, inclusive, control the selection and actuation of the sources of coloured light: red, green and blue, the manner of doing which will presently be described. When the switch 19 is operated to the left (as shown in Fig. 5), two white lights, W1 and W2, are connected in parallel between the contact member 2 of the dimmer 28 and conductor 101 of the supply circuit, the connection including the left-hand contacts of the switch. Upon the movement of the members 32 of that switch to its right hand contacts, the white lights will be connected in series with each other, which, as shown by the curve Y in Fig. 3, will cut down the illumination given by each of the white lights to about 10% of the maximum intensity in lumens that each is capable of producing at its normal voltage, e.g., 120 volts.

The manner in which the circuit of Fig. 5 operates to control the colour lighting system is as follows: It will be assumed that the movable members 32 of the switch 19 are upon the right hand contact points of the switch which connects the white lights W1 and W2 in series with each other, and that the knob 32 has been turned sufficiently to effect the operation of the switches C, D and F, as shown at the left hand side of Fig. 2. The operation of switches C and D applies the dimmer voltage to the source of green light, but no illumination will result therefrom, since, as shown in Fig. 3, the voltage of the dimmer at that instant is the minimum. Since switch F is also operated at that time, the full line-voltage will be applied to the source of blue light which will produce illumination of maximum intensity. Since the white lights, W1 and W2, are also connected to the dimmer, no illumination will be produced by them at that instant, therefore, at the beginning of the colour cycle the illumination will come from the blue source, but as the knob 32 continues to move through the range from 0° to 60°, the intensity of the green light will gradually increase and will reach its maximum at 60°; the intensity of the white light will also increase and reach its maximum at 60°; but since the white lamps are in series (the voltage across each lamp is one-half the normal voltage) the intensity of the white light is greatly limited, as shown by curve Y. This effects the creation of pastel hues as described hereinbefore with reference to the circuit of Fig. 1. Near 60° of the colour cycle, as shown in Fig. 2, switch C will be released by the operation of cam 13, and shortly thereafter switch E will be operated so that, as shown in Fig. 2, switches D, E and F will then be operated. The operation of switches E and F connects the blue source of light to the dimmer, and the operation of switch D connects the green source across the line. Since the dimmer voltage falls throughout the range of 60° to 120°, the intensity of the light from the blue and the white sources will diminish thus leaving the light from the green source dominating at the end of the cycle. In similar fashion, the several sources of coloured light will be activated by the operation of the switches under the control of the cams in the sequence shown in Fig. 2, and the resulting deep hues of colour will be pastelled by the relatively small amount of white which is represented by curve Y of Fig. 3. When it is desired to increase the in-

tensity of the white light, the switch-arms 32 are moved to the left hand contacts of the switch 19 thereby connecting the lamps in parallel between the dimmer and the neutral side 101 of the supply circuit. This effects a marked increase in the intensity of the light given by the white lamps, as shown by the curve X in Fig. 3, which reaches its maximum at 60°. Thereafter the intensity of white illumination diminishes up to 120° of the colour cycle, when it becomes practically nil. The dimmer voltage cycle is repeated between 120° and 240°, and between 240° and 360° as shown in Fig. 3. The intensity of the white light is so great as to dominate the illumination, the deep colours serving merely to tinge the white light. The resulting illumination therefore is a range of near-white light.

In the foregoing description of the control apparatus disclosed in circuit form in Figs. 1 and 5 and in mechanical form in Fig. 4, only manual operation of the apparatus has been mentioned, but it is not limited to that mode of operation. The apparatus may be operated either manually or by power, as by an electric motor or other suitable means as is shown in Figs. 6 and 6A. The arrangement shown in Fig. 6 provides not only for the selection of particular hues by manual operation of the apparatus but also makes possible, by a motor drive, the continuous production of the entire range of hues of colour in sequence. As there shown the shaft 20 to which is fastened the pinion 21, which is normally in engagement with the gear 29 for manual operation of the apparatus, is arranged to be moved longitudinally, as shown in the figure, so as to move the pinion into engagement also with the gear 37 when continuous operation of the apparatus is desired. When the pinion 21 is in engagement only with the gear 29, operation of the control apparatus is effected manually by rotation of the knob 32 precisely in the manner heretofore described. When continuous rotation of the cams is necessary in order to produce the entire range of hues of colour in sequence, shaft 30 may be driven by a motor such as 38 in Fig. 6A, or other source of power which may be connected directly to the shaft 30 or indirectly, as shown in that figure, by a belt or chain drive. The driving force is applied to a sprocket, as 34, which is fastened to the shaft 36 to which is also fastened the gear 37, which, as mentioned, is normally disengaged from the control apparatus. In order to render the gear 37 effective to drive the cams and the arm that controls the auto-transformer, the shaft 20 is moved inwardly, that is, to the left as shown in Fig. 6, to such extent as to bring the pinion 21 into engagement also with gear 37. Thereupon the continuous rotary movement of the gear 37 will be transmitted through the pinion 21 to the gear 29, which, in turn, will effect the continuous rotation of the cams 11 to 16, inclusive, and the operation of the switches A to F, inclusive, as well as the oscillatory movement of the arm 24. When continuous operation of the control apparatus is no longer desired, it may be stopped by withdrawing the pinion 21 from engagement with the gear 37. The pinion will, thereafter, remain in engagement with the gear 29 for manual operation of the apparatus.

In order to prevent the pinion 21 from becoming disengaged from the gear 37 while the apparatus is being driven by the motor, holding means has been provided which prevents the shaft from moving toward the right, as shown in Fig. 6, after it has been pushed to the left to effect the engagement of the pinion and said gear. The holding means there shown includes a member 49 to which a knob 50 is fastened, said member extending through the wall 52 of the casing and being movably supported thereby. The member 49 has an arm 47 rigidly fastened thereon which, as shown in enlarged form in Fig. 6B, has a notch therein near its outer end, the width of the notch being slightly greater than the diameter of the shaft 20 to permit engagement of the shaft by the arm, the purpose of which will presently be made clear. Between the knob 32 and the wall 52 of the casing is a spiral spring 51 which encircles the shaft, said spring being intended to apply the force required to withdraw the pinion 21 from engagement with the gear 37 upon the disengagement of the locking means. A collar 48 is securely fastened to the shaft 20 the cylindrical face of the collar being sufficiently broad to permit the arm 47 to rest thereon after the pinion has been withdrawn from engagement with the gear 37. The collar is so positioned upon said shaft and the width of its cylindrical face is such that when the pinion 21 has been moved by the shaft into engagement with the gear 37 the arm 47 will be brought into engagement with the shaft 20 at a point upon said shaft between the collar 48 and the wall 52. The collar 48 will then be firmly held against the arm 47 by the action of the spring 51, thereby preventing the shaft from moving toward the right, as shown in Fig. 6. Accordingly, the pinion 21 will be securely held in engagement with the gear 37. When it is desired to withdraw the pinion from engagement with the gear 37, the knob 50 is turned in clock-wise direction thereby causing the arm 47 to move through sufficient angular distance to permit the collar 48 to pass thereunder when the shaft 20 is drawn to the right (as in Fig. 6) by the action of the spring 51. The form of locking device shown in the drawing and described herein is purely by way of illustration since it is obvious that other forms of

locking devices within the scope of the present invention may be employed to effect the same result.

When continuous operation of a plurality of control units such as 60 to 62, inclusive, is desired by a single source of power, an arrangement such as is shown in Fig. 6A may be employed. In that figure, which is a rear view of a group of three units, a motor, represented by 38, is shown mounted upon the topmost unit and connected to the control mechanism in each of said units by either a belt drive or a chain and sprocket drive, but the motor may be placed in other positions in relation to the units, if desired. Obviously, any number of units desired may be driven by a single motor of suitable power, but in order to keep a plurality of units in alignment a suitable framework is necessary, such, for example, as is represented by dot-and-dash lines in Fig. 6A.

Although the motor is shown in Fig. 6A connected to all units, it should not be implied that all units must be operated simultaneously. As mentioned hereinbefore, each control unit may be readily adjusted for operation, either manually or by motor drive, as desired, by shifting the position of the pinion in the unit. For example, if it is desired to maintain constantly a definite hue of colour by the light sources controlled by one of the units, for example, 61, and at the same time produce repetitively the range of colours of the light sources controlled by the other control units, 60 and 62, that result may be obtained by maintaining the pinion 21 of unit 61 out of engagement with the gear 37 and at the same time keeping the pinions of the other units in engagement with the gears 37 of those units. The control unit 61 would, of course, be adjusted to effect the production of the desired hue of colour by the lights controlled thereby in the manner fully described hereinbefore.

Figs. 7 and 7A show other ways in which the normally inactivated source of coloured light may be employed in the circuit shown in Fig. 1. The arrangement shown in Fig. 7 shows the manner in which the normally inactivated source of colour may be employed to pastel the two activated sources of colour in a three-colour lighting system. As shown in that figure, a resistance 54 is provided, the magnitude of which is sufficient to reduce the light value of a coloured source of light to a desired level. The resistance 54 is connected between contact member 2 of the dimmer and the movable member 17*a* of the switch 9*a*. When the switch is closed by moving the member 17*a* into contact with 8*a*, the normally inactive coloured lamp, such as the red lamp indicated, is connected to the dimmer, the connection including the contactor 2, resistance 54, switch 9*a*, conductor 45, contact 7 of switch B, and the red lamp. Accordingly, the red lamp would be activated, but at a lower intensity than would be the case if the lamp were connected directly to the dimmer. Since red is the complementary colour of the hue resulting from blue and green (which are the normally activated colours when red is normally inactivated), the red light has a pastelling effect upon the resulting hue of blue and green. The arrangement shown in Fig. 7A provides for the connection of a normally inactivated lamp in series with the resistance to pastel the resulting hue of the other two colours, or to use the normally inactivated lamp as a resistance to reduce the intensity of a white source of light in pastelling the darker hues. When the switch 58 is operated to close the contact 55-56, the normally inactivated lamp R will be connected in series with the resistance 54*d* and thereby will become activated but at a low light value. When it is desired to use the inactivated colour source as a resistance to reduce the intensity of the source of white light, the switch 58 is operated to close its contact 55-57, and switch 9 is operated to close its contact 17-8, thereby connecting the normally inactivated source of coloured light R in series with the source of white light W. If it is not desired to reduce the intensity of white light, the switch 9 is operated to close its contact 17-18, thereby connecting the white lamp directly between the dimmer and conductor 101 of the supply circuit thereby increasing the range of near-white tints. The term "normally inactivated" as used herein to characterise a source of coloured light, means that the light source so characterised is one that, during the normal operation of the apparatus, is at a given moment not connected to any source of potential: for example, in Fig. 1 (when operated as a 3-colour system) the red lamp is "inactivated" at 0° when the green lamp is connected to the dimmer and the blue lamp is connected to the power line; similarly, the blue lamp is "inactivated" at 120° when the red lamp is connected to the dimmer and the green lamp is connected to the line; and likewise, green is "inactivated" at 240° when blue is connected to the dimmer and red is connected to the line. When the "normally inactivated" colour source is connected in series with the white source as in Fig. 1 (when operated as a 4-colour system) or in series with a resistance as in Figs. 7 and 7A, it, of course, becomes activated by the voltage of said dimmer.

Figs. 8 and 8A show other arrangements by which the intensity of white light in the circuit shown in Fig. 5 may be controlled. In Fig. 8 the white lamp W3 is shown connected in series with resistance 33, the magnitude of which is sufficient to reduce the maximum light value of the source W3 to

the desired level. A switch may be provided to shunt the resistance 33 when it is desired to apply the full dimmer voltage to that lamp. Fig. 8A shows another way of controlling the intensity of white light from the source W4 which consists in connecting one side of the lamp to a tap on the winding of the auto-transformer, the tap being so placed that the maximum voltage applied to the lamp by the transformer will not exceed a desired value. A switch 66 is provided to close or open the circuit of the lamp W4 as desired. While the aforedescribed methods of controlling the intensity of the white light may be employed, the preferred method is that in which the normally - inactivated coloured lamp is employed as a resistance to limit the voltage applied to the white lamp and, in consequence, to reduce the intensity of illumination produced thereby.

While the voltage-varying device has been represented in the various figures as an auto-transformer and has been so referred to hereinbefore, it is to be understood that other forms of voltage-varying devices may be employed, such as (but without limitation) saturable reactors, electronic devices, or resistors. The term "dimmer" as used herein is intended to be generic to all such voltage-varying devices.

It is to be understood that the term "white" wherever employed in the specification and claims, to characterize the colour of light, is intended to mean a more desaturated colour than the other colours employed in the lighting system, the degree of desaturation ranging from that represented by a paler hue than the other colours employed to 100% desaturation, that is, pure white.

Furthermore, it is to be understood that the invention is not limited to the use of the specific colours of the sources of light mentioned hereinbefore and indicated upon the drawing. All of said sources may be of the same colour or all white, or any combination of colours desired.

Though the invention has been described as embodied in particular forms and arrangements of parts, it is to be understoood that it is not so limited but is capable of embodiment in other and different forms and arrangements without departing from the scope of the appended claims.

What I claim is:—

1. Control apparatus for colour lighting comprising a plurality of electrical sources of coloured light and an electrical source of light of paler colour than those of the other sources, a single variable dimmer, switching means for the coloured light sources which enables one coloured light source to be connected to an electrical supply at full voltage and another coloured light source to be connected to the supply through the dimmer, operating means for the switching means and the dimmer, and further switching means to enable the paler source of light to be connected to the supply either directly through the dimmer or through the dimmer and a source of coloured light not in any other way connected to the supply.

2. Lighting control apparatus according to Claim 1 having a single operating member to operate the first mentioned switching means and dimmer progressively through a complete cycle of colour change whereby each coloured light source in turn is brought from minimum to maximum intensity gradually, is maintained at maximum intensity for a period and then returned to minimum intensity gradually, and wherein each terminates its said period of maximum intensity as or approximately as the next in turn begins its same period.

3. Lighting control apparatus according to Claim 1 or 2, having three electrical sources of coloured light, wherein said further switching means is adapted, when operated, either to connect the light source of paler colour alone to the supply, or to connect such source to the supply in series with the coloured light source not otherwise connected at that time, the connection in each case being in series with the dimmer.

4. Lighting control apparatus according to Claims 2 or 3, wherein a resistance is provided in series with the light source of paler colour.

5. Lighting control apparatus according to any of the preceding claims wherein the light source of paler colour is a white light source.

6. Lighting control apparatus according to Claim 1 having three electrical sources of coloured light in which the switching means for selecting a source of coloured light and applying the dimmer voltage thereto, comprises a single operating member for the dimmer, arranged simultaneously to maintain the application of a constant voltage to another of the said sources of coloured light and to connect the third source of coloured light in series with the light source of paler colour and said dimmer.

7. Lighting control apparatus according to Claim 6 in which said switching means is further arranged simultaneously to connect the third source of coloured light in series with said dimmer, said connection including means to limit the voltage applied to said third source of light.

8. The combination defined by Claim 7 characterised in that the number of operating cycles through which the dimmer voltage passes to produce the full range of hues of the colour cycle equals the number of sources of coloured light employed in the system, and further characterised by the interchanging of the connections of the first and the second sources of light with their respec-

tive sources of voltage when the dimmer voltage is maximum whereby the constant voltage will be applied to the first selected light source and the dimmer voltage to the second selected light source.

9. Lighting control apparatus comprising three coloured electrical light sources, each of the colours of which is approximately the complementary colour of a hue, an electrical light source of paler colour, a pair of switches associated with each of the coloured light sources, and a plurality of rotating cams for operating the respective switches, a rotary dimmer and means for rotating the cams and dimmer simultaneously so that each light source in turn is brought gradually from minimum to maximum voltage, is maintained at maximum voltage and is then brought gradually back to minimum voltage, and so that each source begins to decline in voltage after the next in turn has reached the maximum with separately-operated switch means for connecting the other coloured light source, or the paler light source, or both, to the supply in series with the dimmer.

10. An arrangement according to Claim 9 wherein on reaching maximum voltage each light source is switched out of circuit with the dimmer into direct contact with the supply and is returned into circuit with the dimmer at the end of its period of maximum voltage.

11. An arrangement according to Claim 10 comprising mains conductors, a continuously variable ratio auto-transformer across those conductors, switches for connecting each coloured light source directly across the conductors, further switches for connecting each such source across the movable contact of the transformer and one of said conductors, and means for operating all said switches and the transformer through a cycle to give the variations claimed in Claim 9.

12. An arrangement according to Claim 10 or 11 wherein the switches are micro-switches, for example giving an interruption period of 1/200th of a second or thereabouts.

13. Lighting control apparatus according to Claim 2 wherein the single operating member returns the dimmer and the switching means to the same relative positions after rotation through 360°.

14. A lighting control apparatus according to Claim 13 wherein each voltage is applied to each of the coloured light sources for 120° of the colour cycle and wherein the switches change the connections of the dimmer to colour sources at approximately each 60° of the colour cycle.

15. The arrangement of Claim 13 or 14 wherein the rotary members are adapted for continuous rotation to give a repetitive performance of the cycle, and wherein the said third source for the time being may be put out of circuit at will.

16. The arrangement of Claim 13, 14 or 15 wherein during the first half of any phase of 120° of the colour cycle in which a first light source remains at maximum voltage, a second source which was at maximum voltage during the next preceding phase has a decreasing dimmer voltage applied to it, whilst the third source is in series with the paler light and the dimmer; and during the second half of such phase the said third source has an increasing dimmer voltage applied to it whilst the said second source is in series with the paler light and the dimmer.

17. The arrangement of any of Claims 11-15, wherein the rotary cams are mounted on a common spindle for simultaneous rotation, and the dimmer is mounted for rotation at three times the rate of revolution of the cams.

18. The arrangement of Claims 17 wherein said spindle is associated with a scale and pointer, the scale being calibrated to indicate the hues of colour resulting from any position of the cams and dimmer.

19. An arrangement according to Claim 17 or 18 wherein the cams and dimmer are adapted for manual and power operation selectively.

20. A plurality of the arrangements claimed in Claim 19, adapted to receive the power drive from a common source.

21. An arrangement according to any of Claims 16-20 wherein a power drive is provided, including a rotating pinion, wherein the or each cam spindle has a pinion associated with it, and wherein a control member for manual operation of the cams is adapted constantly to be in driving connection with the second-named pinion and to be brought selectively into driven engagement with the first-named pinion.

22. An arrangement according to Claim 21, having means for locking said control member in driven engagement with said first-named pinion.

23. An arrangement according to Claim 21 or 22, constructed substantially as illustrated in Figs. 6 or 6A of the accompanying drawings.

24. A lighting control apparatus wired in a circuit as or substantially as shown in Fig. 1 of the accompanying drawings.

25. A lighting control apparatus according to Claim 1, with or without the characteristic of any of Claim 2-20, wherein two white light sources are provided, and wherein there is switching means whereby said sources may be connected in series or in parallel with each other, at will.

26. An arrangement according to Claim 25, wired in a circuit as, or substantially as shown in Fig. 5 of the accompanying draw-

ings.

27. Lighting control apparatus according to any of Claims 1-4, wherein a resistance is provided, along with switching means adapted selectively to put such resistance in series with the dimmer and the coloured light source which for the time being is otherwise inactive.

28. An arrangement according to Claim 27, wired in a circuit as or substantially as shown in Fig. 7 of the accompanying drawings.

29. A lighting control apparatus according to any of Claims 1-24, modified as or substantially as herein described with reference to Fig. 7A, 8 or 8A of the accompanying drawings.

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Chartered Patent Agents.

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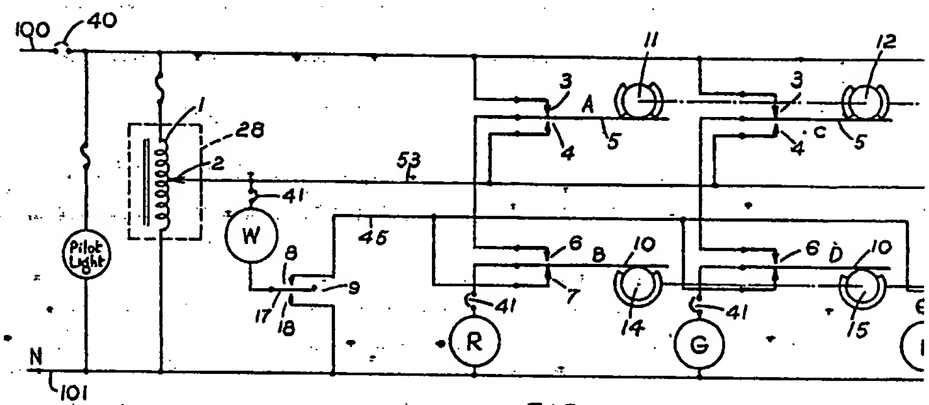


FIG. 1.

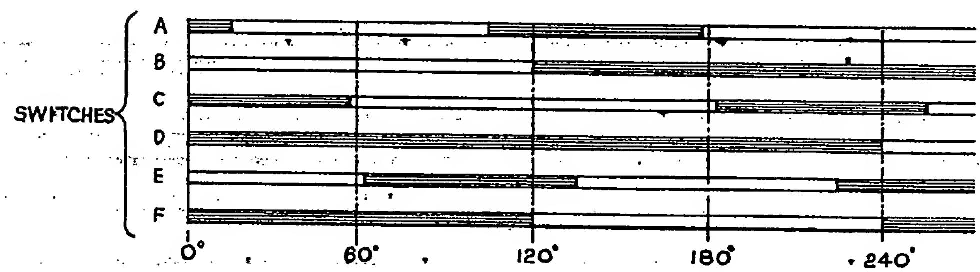


FIG. 2.

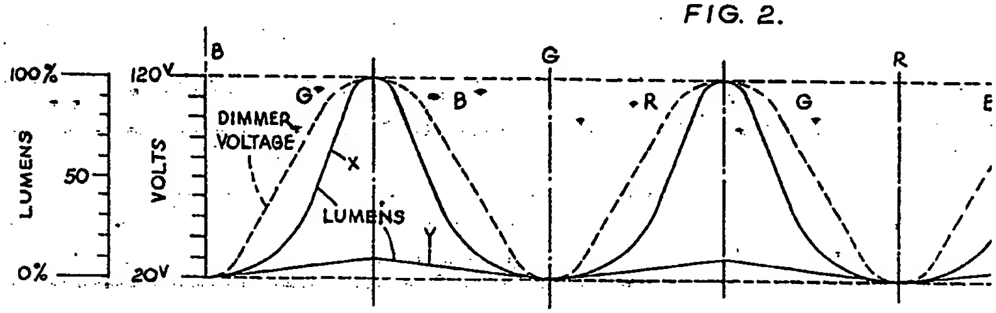
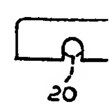


FIG. 3.



712,050 COMPLETE SPECIFICATION

3 SHEETS

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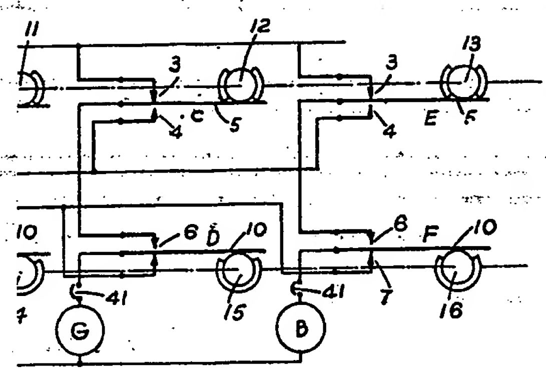

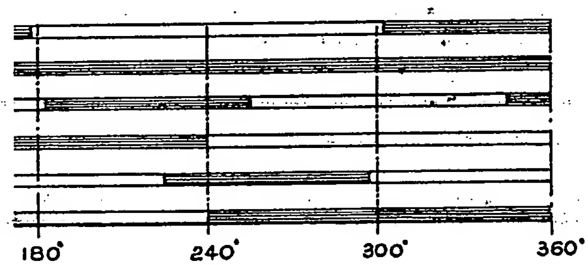

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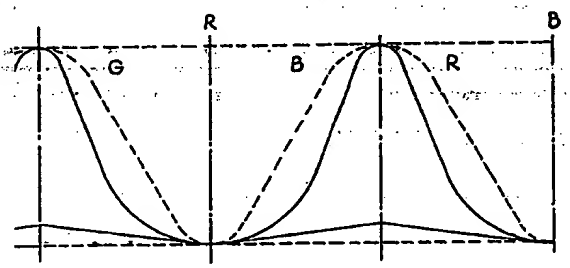

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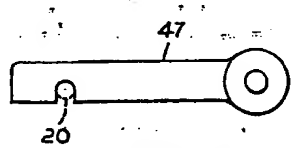

FIG. 6B.

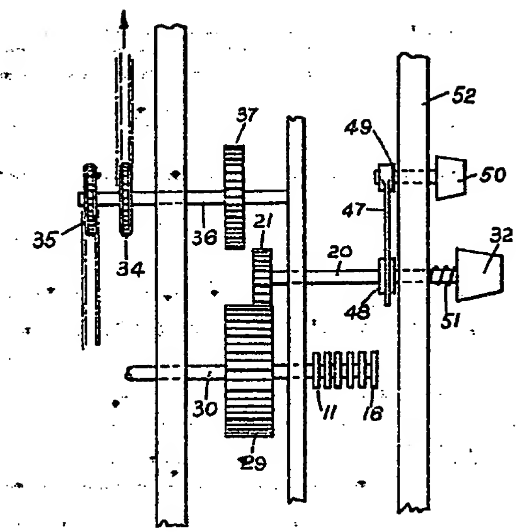

FIG. 6.

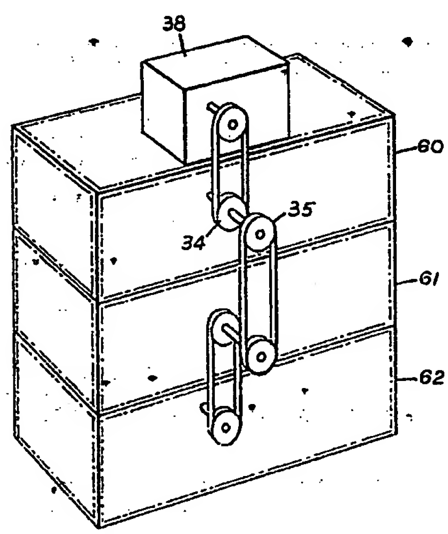

FIG. 6A.

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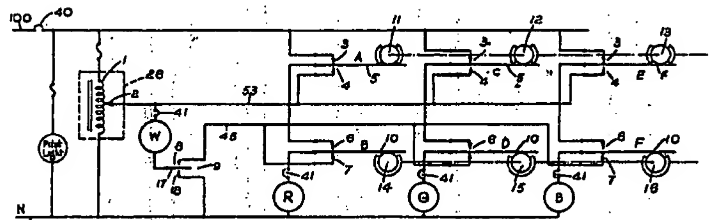

FIG. 1.

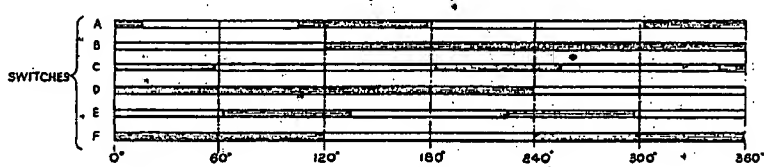

FIG. 2.

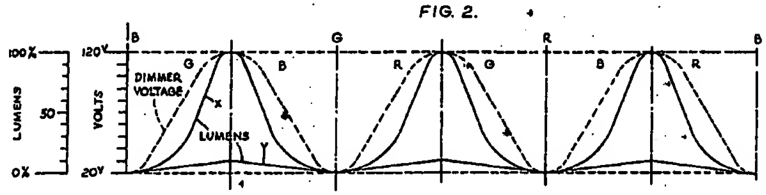

FIG. 3.

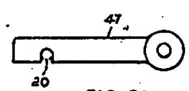

FIG. 6B.

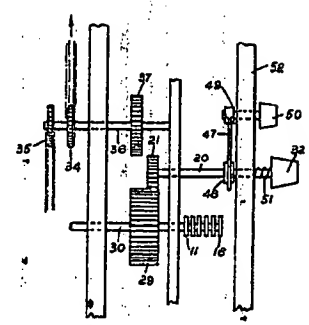

FIG. 6.

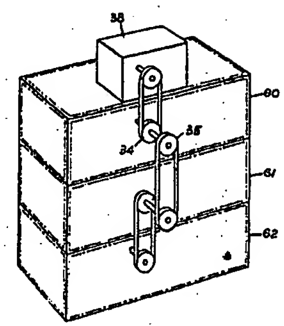

FIG. 6A.

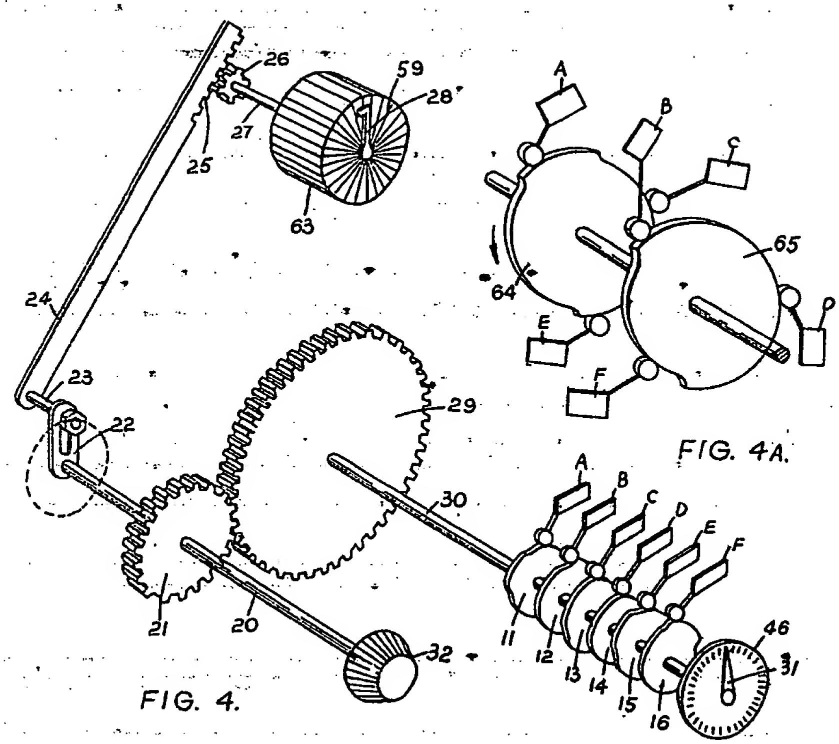

FIG. 4.

FIG. 4A.

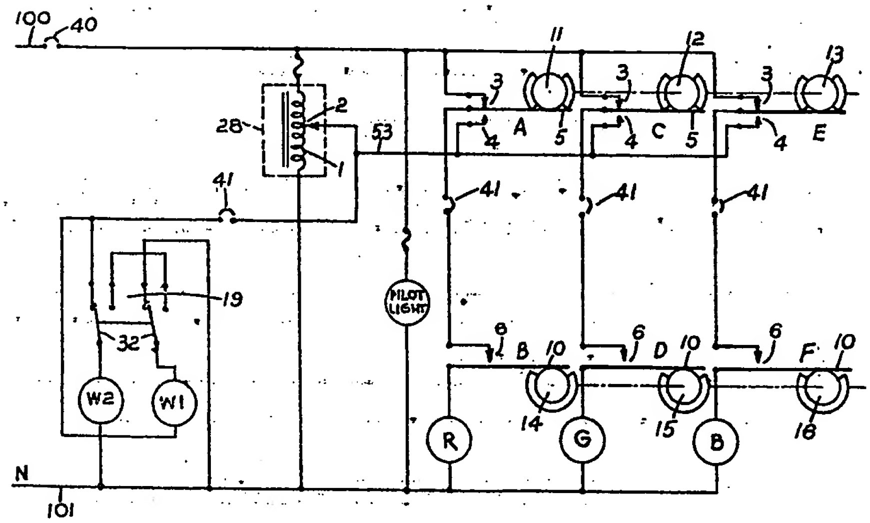

FIG. 5.

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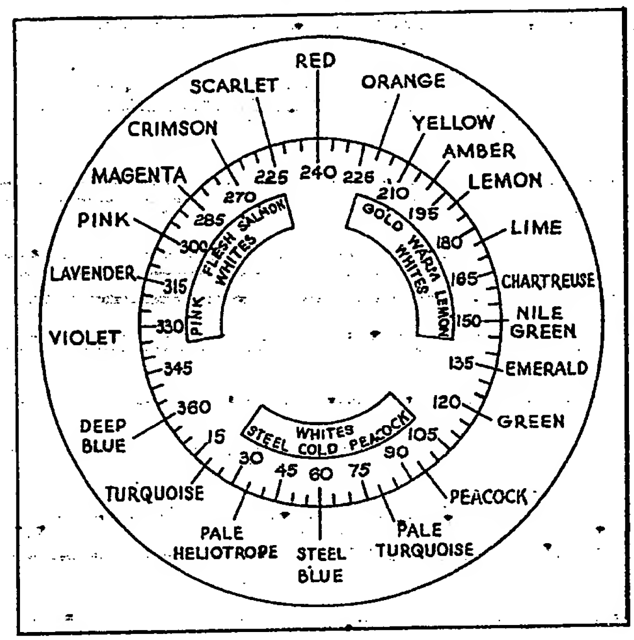
SHEETS 2 & 3

FIG. 9.



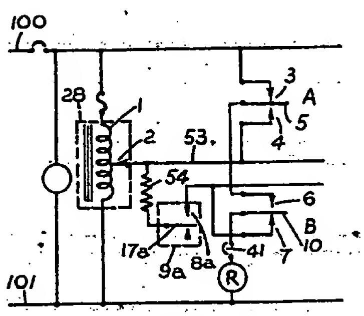


FIG. 7.

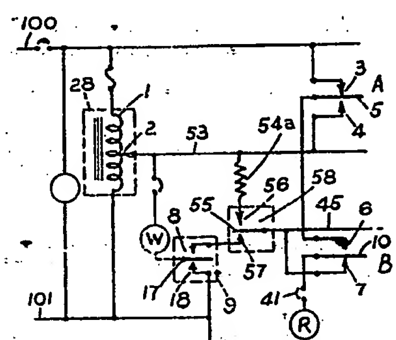


FIG. 7A.

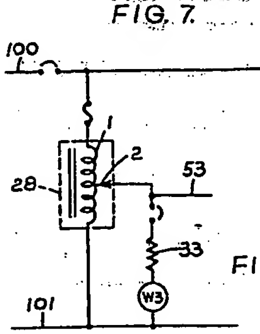


FIG. 8.

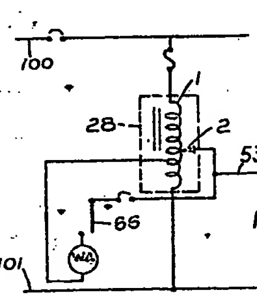


FIG. 8A.

712,050 COMPLETE SPECIFICATION
3 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

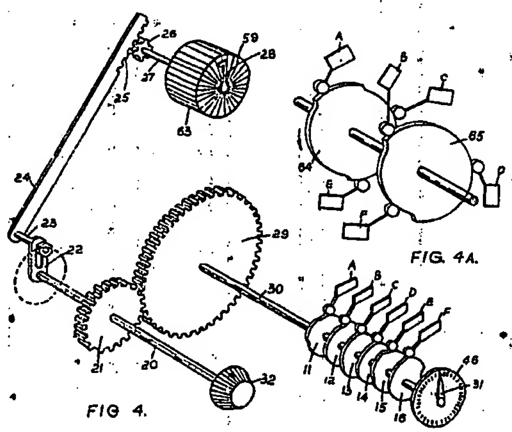


FIG 4.

FIG. 4A.

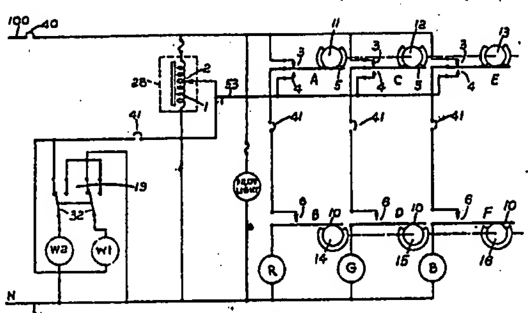
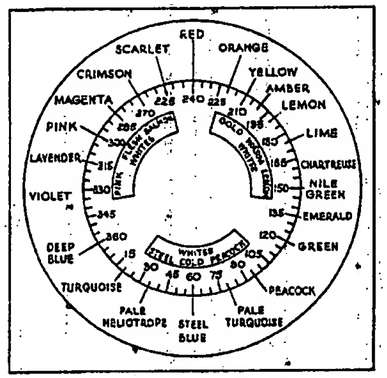


FIG. 5.

FIG. 9.



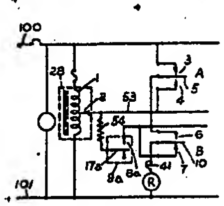


FIG. 7.

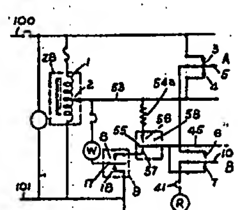


FIG. 7A.

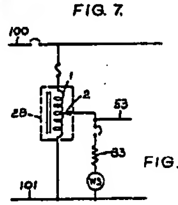


FIG. 8.

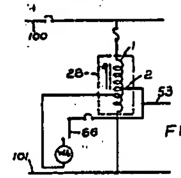


FIG. 8A.